page 408 (5) the mean flow should reach a level toward the period 1945–1950 which may be 500 cubic meters per second greater than the present long-term average. The increase in the general mean of 1,600 cubic meters per second would amount to as much as 31 per cent. This latter estimate is necessarily uncertain and depends on the expectation that the "secular" cycle will repeat itself in the future with similar amplitudes as in the past. Accurate records are too short to conclude this with the same degree of probability as is possible in the case of the Horton cycle.

Thus the great Borysthenes of the anicent Greeks demonstrates the apparently close relations between variations in streamflow and the solar cycle. The records on which the above investigation is based were obtained by courtesy of Mlle. T. Maretsky, chief hydrologist, Nijne Dnieper, Moscow, Union of Socialist Soviet Republics.

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SANDSTORMS IN TEXAS

By JOHN A. RILEY

[Weather Bureau, Dallas, Tex.]

Large volumes of sand and dust are occasionally raised by the wind in dry weather over the western plains of the United States. These storms are of three distinct types: (*a*) Strong winds blowing across the plains sometimes attain gale force over a wide area and pick up large quantities of dust, particularly in late winter and early spring when the ground is bare and especially over cultivated land. Such winds attain their highest velocities during the day. (*b*) The second type is the whirlwind, very local and of minor importance; these whirls, sometimes called "sand devils," occur on hot summer afternoons when the lapse rate equals or exceeds the adiabatic. From an airplane they can be seen for miles and easily avoided. (*c*) The most spectacular storms appear to form along the wind-shift line of a barometric trough; they may therefore be expected when cyclonic activity is at a maximum.

Figure 1 shows a sandstorm approaching Big Spring, Tex., on the afternoon of September 14, 1930. It occurred in an elongated LOW that moved eastward across Texas on that date. The trough of low pressure extended at least from the Rio Grande Valley to northern Kansas. At 10 a. m. (ninetieth meridian time) there was a moderate sandstorm at Abilene, with a 20-mile south wind, and thunderstorms were occurring near Wichita Falls, Tex., Oklahoma City, Okla., and Springfield, Mo. At 1 p. m. there were fresh southerly winds from central Texas to Kansas and moderate northerly winds in the Panhandle and west Texas. At 4 p. m. Amarillo reported "moderate sand storm since 1 p. m.," and thunderstorm activity continued in the northern end of the trough, in Missouri. At 7 p. m. scattered thunderstorms were reported from the middle Rio Grande Valley to Kansas and Missouri.

The exact time of the Big Spring storm is not known, but judging from the shadows cast by the sun in Figure 1, it was approaching from a westerly direction at about 4 p. m. The sun was obscured in the second exposure and it was getting much darker in the third, due to the approach of the wall of dust.

Typical of the dry atmospheric conditions in west Texas, the temperature at 7 p. m. at El Paso was 86 and the dew point, 17; at Amarillo, 78 and 35, and at Abilene, 94 and 34. These conditions give rise to "dry squalls" in the semiarid plains of the West—a sudden shift of the wind through 90° or more generally from a southwesterly to a northwesterly direction. The speed of the wind in some of these dry squalls at times reaches gale force and is very gusty. In more humid regions these wind shifts are accompanied by thunderstorms and line squalls.

While the dry squalls do not usually equal in violence the line squalls of humid regions they are always very turbulent and at times violent. Except for the dust they may be practically invisible to the pilot in the air. Pilot J. G. Ingram relates that a few years ago he was flying across a wind shift in west Texas, when the ship dropped a thousand feet and was then carried up above its previous level, accompanied by violent turbulence. Pilot Homer Rader, flying between Dallas and El Paso, passed over a dry wind shift in west Texas late in 1930. From an altitude of 5,000 feet the ship settled slowly at first and then ran into a really violent windstorm, without rain or clouds. The ship was carried up 1,500 to 2,000 feet and dropped a like amount. The air was so rough that control of the ship was at times taken from him, and to relieve the strain the ship was allowed partly to adjust itself to the shock of the variable movements of the air.

Severe sandstorms for more than a short time are unusual, and flights are seldom canceled because of them, for, although the visibility may be zero at times, the dust comes in waves with the gusts of wind, and during the lulls the visibility improves enough for flight.

At times the sand drifts along the ground like drifting snow obscuring the ground but not rising to any great extent. Dust enough to interfere with visibility occasionally rises to 10,000 feet or higher, but it is more likely to be below 6,000 feet so that the pilot can climb above it. At other times the dust rises in columns like cumulus clouds and the pilot can fly around it.

The downward draft of a strong wind blowing across a mountain range often has a focus where it strikes the ground in the lee of the mountain, raising a layer of dust as well as making landing dangerous on account of the currents which are extremely variable in direction and force.

The following notes on sandstorms are furnished by Mr. W. H. Green, Weather Bureau official at Abilene, Tex.

> Most of our sandstorms occur with moderately high westerly winds, being rather severe when the wind reaches 33 miles or above. They seem to be most severe when the wind is from west-northwest. High winds from other directions sometimes cause considerable dust but usually precede thunderstorms and are therefore of short duration.
>
> The severity of the sandstorm depends to a very great extent on whether or not the ground is bare or covered with vegetation

FIGURE 1.—Sand storm approaching Big Spring, Tex. Photo by Bradshaw

even considerably more than on the current rainfall. We are not bothered much with sandstorms when the rainfall is normal or above and reasonably well distributed (some exceptions, however), while we occasionally have rather severe sand or dust storms a few hours after a heavy local rain.

The extent of the sandstorm is probably about the same as the extent of the high winds and the bare ground. I have personally seen much worse sandstorms on the plains of Texas, around Plainview, than I have seen in this vicinity; and Abilene people, who have occasion to be in El Paso at the same time that we have a sandstorm in this vicinity, occasionally come back and report that "New Mexico and Arizona both passed through El Paso the day before."

The visibility in a sandstorm varies, of course, with the intensity: In extreme cases it is perhaps not over 100 feet for a few minutes at a time, 300 feet for 30 minutes to an hour, not much over a quarter mile for 2 or 3 hours, and perhaps one-half mile for 4 or 5 hours. The most severe sandstorms occur in the day time, and are sometimes rather severe from about 9 or 10 a. m. to about 7 or 8 p. m.

Most of the sandstorms occur during February, March, and April, these months usually being comparatively dry, until after the middle of April, and the ground usually being bare or almost so, especially that in cultivation, until about the 1st of May, except an occasional year when considerable small grain is planted.

The Big Spring sandstorm bears a striking resemblance, as was pointed out by Prof. A. J. Henry, to the haboobs of the Egyptian Sudan, a photograph of which was reproduced in the Quarterly Journal of the Royal Meteorological Society January, 1925, with an account by L. J. Sutton. Sutton states that the haboob is a dense mass of whirling sand usually accompanied by a strong wind, but he does not clearly distinguish it from other sandstorms. Col. H. G. Lyons, commenting on Sutton's paper, suggests the similarity between haboobs and line-squalls. The haboobs he had experienced appeared as a front of violent upward and downward currents, in which the most striking feature was a mass of dust often thick enough to cause extreme darkness. Lyons thought the term should not include very strong dust-carrying storm, but be limited to circular storms which occur during periods of atmospheric instability. Haboobs in Nubia, he observes, usually come from the southeast and as they pass the wind veers round quickly to northwest, the sky clears and it is definitely colder.

Similar conditions have been noted by pilots in west Texas; shortly after the worst of a sandstorm had passed a cold layer of air near the ground was found to be overrun by a warm layer at about a thousand feet. It appears, therefore, that there is more than a superficial resemblance between the haboob and the Big Spring storm.

THE FOREST FIRE-WEATHER SERVICE IN THE LAKE STATES

By J. R. LLOYD [1]

[Weather Bureau, Chicago, Ill.]

It is doubtful if the average person grasps the enormity of the waste that has been, and is still being caused, in our great forests, which form a large portion of our northern woodlands. In order to acquire a true conception of the situation it is necessary for one to travel through the forests, noting the extent of the areas burned over and the damage that has been done, and to study forest fire statistics.

While no fires of really great extent have occurred in the Lake States in late years, the great Minnesota fire of October 12, 1918, stands out as an example of what might happen again if it were not for the eternal vigilance of the fire protection organizations; and there are times, when weather conditions go against them, that they are almost helpless. This great conflagration was the result of several factors operating in unison. The summer of 1918 in Minnesota was dry and warm, causing the grasses and other small vegetation on the forest floor to dry out and die much earlier than usual. This was followed by a dry autumn, which increased the fire hazard tremendously. Minnesota has much swamp land, and most of the swamps are filled with peat. There are more than 5,000,000 acres of peat land in Minnesota, of which a large portion had been drained prior to 1918.

Therefore, when the drouth of that year developed these peat lands dried out and became the chief source of trouble. Fire in peat is exceedingly difficult to extinguish. Some peat fires have been known to burn from one summer to another, even under a heavy covering of snow during the intervening winter. It so happened in 1918 that the State Forest Service of Minnesota lacked sufficient funds to meet this emergency, due largely to political dissension among State officials and legislators. This was exceedingly unfortunate. Many small fires were started in the peat lands that were not extinguished because of this lack of funds and personnel. These fires smouldered along until there came a day, October 12, with clear sky, low relative humidity, mild temperature and, fresh southwest winds. Then these smouldering fires spread, picked up momentum, merged into one great fire—the greatest of record in this country—and swept on, destroying nearly every living thing in its path. It traveled at great speed, and created winds powerful enough to pull up by the roots large trees. It swept over nearly a million acres in one afternoon and the early part of the following night, snuffed out the lives of nearly 1,000 human beings, killed thousands of domestic and game animals and birds, and destroyed probably $75,000,000 worth of forests and property. The city of Duluth had a very narrow escape, being saved principally by a high range of hills in the rear that parallel the shores of the lake and the bay. This great conflagration is mentioned as an example of what can happen in the northern woodlands when weather conditions are just right.

Since weather conditions play a major rôle in forest fire protection and suppression, it therefore follows that if the forest protective organizations know what to expect in weather for even a day or two in advance that they will be in a position to act on a given situation to better advantage. Therefore, the fire-weather service in the Lake States was created to supply a demand, voiced by the fire protection organizations, for weather forecasts and other weather information that might help them in combatting this red scourge that has cost so many millions of dollars in money, and taken so many thousands of lives of human beings and denizens of the wild.

The project was started in Minnesota during the summer of 1926. From a modest beginning in 1926 the service has been gradually expanded. It was organized in Wis-

[1] In charge fire-weather project in the Lake States.